PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : C12N 15/86, 15/49, A61K 35/76, C12N 7/00, 5/10 — A1

(11) International Publication Number: WO 98/17816

(43) International Publication Date: 30 April 1998 (30.04.98)

(21) International Application Number: PCT/GB97/02858

(22) International Filing Date: 17 October 1997 (17.10.97)

(30) Priority Data:
9621680.9 17 October 1996 (17.10.96) GB

(71) Applicant *(for all designated States except US)*: OXFORD BIOMEDICA (UK) LIMITED [GB/GB]; Medawar Centre, Robert Robinson Avenue, The Oxford Science Park, Oxford OX4 4GA (GB).

(72) Inventors; and

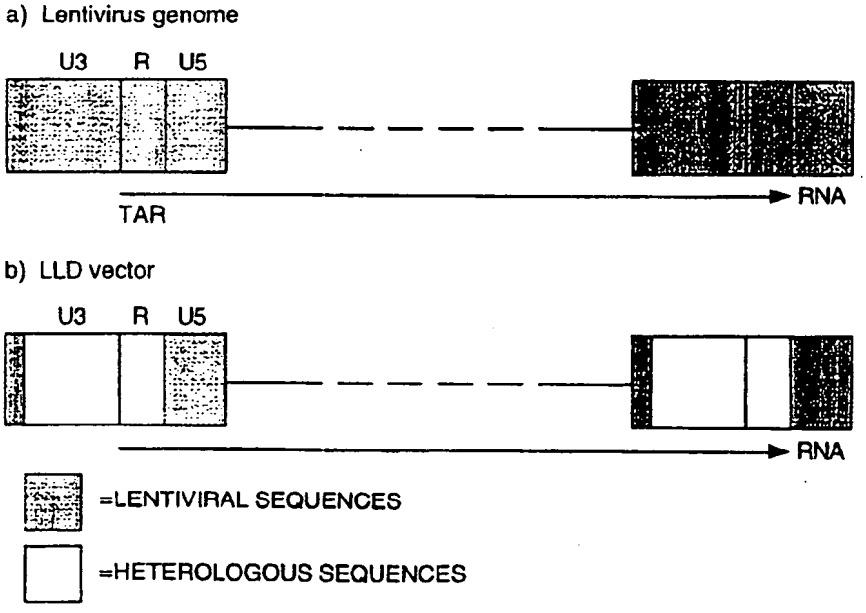
(75) Inventors/Applicants *(for US only)*: KINGSMAN, Alan, John [GB/GB]; Greystones, Middle Street, Islip, Oxon OX5 2SF (GB). KINGSMAN, Susan, Mary [GB/GB]; Greystones, Middle Street, Islip, Oxon OX5 2SF (GB).

(74) Agent: PRIVETT, Kathryn, Louise; Stevens Hewlett & Perkins, 1 Serjeants' Inn, Fleet Street, London EC4Y 1LL (GB).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: LENTIVIRAL VECTORS



(57) Abstract

Retroviral vector particles capable of infecting and transducing non-dividing mammalian target cells, which vector particles may be based on lentiviruses such as HIV and which have an RNA genome constructed so as to provide in the DNA provirus a non-lentiviral expression control element in the 5'LTR of the provirus.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

LENTIVIRAL VECTORS

This invention relates to retroviral vector particles and to DNA constructs encoding RNA genomes for retroviral vectors. In particular it relates to retroviral vectors capable of transferring genetic material to non-dividing or slowly-dividing cells.

There has been considerable interest, for some time, in the development of retroviral vector systems based on lentiviruses, a small subgroup of the retroviruses. This interest arises firstly from the notion of using HIV-based vectors to target anti-HIV therapeutic genes to HIV susceptible cells and secondly from the prediction that, because lentiviruses are able to infect non-dividing cells (Lewis & Emerman 1993 J.Virol. 68, 510), vector systems based on these viruses would be able to transduce non-dividing cells (e.g. Vile & Russel 1995 Brit. Med. Bull. 51, 12). Vector systems based on HIV have been produced (Buchschacher & Panganiban 1992 J.Virol. 66, 2731)) and they have been used to transduce CD4+ cells and, as anticipated, non-diving cells (Naldini *et al*, 1996 Science 272, 263). However, in general gene transfer efficiencies are not as high as with comparable murine retrovirus vector systems.

HIV-based vectors produced to date result in an integrated provirus in the transduced cell that has HIV LTRs at its ends. This limits the use of these vectors as the LTRs have to be used as expression signals for any inserted gene unless an internal promoter is used. The use of internal promoters has significant disadvantages (see later). HIV and other lentiviral LTRs have virus-specific requirements for gene expression. For example, the HIV LTR is not active in the absence of the viral Tat protein (Cullen 1995 AIDS 9, S19). It is desirable, therefore, to modify the LTRs in such a way as to change the requirements for gene expression. In particular tissue specific gene expression signals may be required for some gene therapy applications or signals that respond to exogenous signals may be necessary.

In murine retroviruses this is often achieved simply by replacing the enhancer-like elements in the U3 region of the MLV LTR by enhancers that respond to the desired signals. This is not feasible with viruses such as HIV because within the U3 and R regions of their LTRs are sequences, known as IST and TAR, which may inhibit gene expression and may or may not be responsive to Tat protein when heterologous, perhaps tissue specific, control sequences are inserted in the U3 region (Cullen 1995 AIDS 9, S19; Alonso *et al*, 1994 J. Virol. 68, 6505; Ratnasabapathy *et al*, 1990 4, 2061;Sengupta *et al*, 1990 PNAS 87, 7492; Parkin *et al*, 1988 EMBO.J 7, 2831)). Even if the signals are responsive it is undesirable to have to supply Tat as it further complicates the system and Tat has some properties of oncoproteins (Vogel *et al*, 1988 Nature 335, 606). Overall, these considerations mean that the R region of HIV and other lentivirus vectors must be removed if effective expression from non-lentiviral sequences in the LTR is to be achieved.

We have described previously in PCT/GB96/01230 a method for replacing both the U3 and R regions of retroviral vector genomes. The observation that R regions could be replaced was surprising as it was previously believed that these were specific to the virus that is providing the reverse transcriptase for the conversion of the RNA viral genome to the pre-integrated form of the proviral DNA. PCT/GB 96/01230 describes in particular retrovirus vectors for delivering therapeutic genes whose expression in the target cell is HIV-dependent. Delivery to non-dividing or slowly-dividing cells is not addressed, and application of the invention to HIV or any other lentivirus-based vectors is not addressed. The general approach described in PCT/GB 96/01230 now provides a means of producing an HIV-based vector with the U3 enhancer and R regions replaced by any sequence of choice providing that appropriate polyadenylation and transcription termination regions are included in the R region.

The present invention provides in one aspect a retroviral vector particle based on a first retrovirus, said retroviral vector particle

capable of infecting and transducing non-dividing mammalian target cells, said retroviral vector particle comprising a packagable RNA genome capable of being inserted into a target cell genome when in the form of a DNA provirus, said RNA genome comprising sequences which provide in the DNA provirus:

a) a non-lentiviral expression control element located in the 5' long terminal repeat (LTR) of the provirus in place of the promoter function of the first retrovirus; and

b) a selected gene or genes under transcriptional control of the non-lentiviral expression control element in a), the selected gene or genes located between the LTRs.

In another aspect, the invention provides a DNA construct encoding the packagable RNA genome for the retroviral vector particle described herein, operably linked to a promoter. In the DNA construct, the selected gene or genes may be present, or be absent in which case the construct has an insertion site e.g. a restriction enzyme site, at which the selected gene or genes may be inserted.

In a further aspect, the invention provides a retroviral vector particle production system comprising a host cell transfected or transduced with a DNA construct as described herein, said system capable of producing retroviral vector particles as described herein.

In yet another aspect, the invention provides a retroviral vector particle production system comprising a set of nucleic acid sequences encoding the components of a retroviral vector particle as described herein.

In still further aspects, the invention provides the use of the retroviral vector particles described herein for gene therapy and in the preparation of a medicament for use in gene therapy; and a method of performing gene therapy on a target cell which method comprises infecting and transducing the target cell using a retroviral vector particle as described herein. The invention further provides transduced target cells

resulting from these uses and methods. The invention thus provides a gene delivery system for use in medicine.

That the vector particle according to the invention is "based on" a first retrovirus means that it is derived from that retrovirus. The genome of the vector particle comprises components from that retrovirus as a backbone. The vector particle as a whole contains essential vector components compatible with the RNA genome, including reverse transcription and integration systems. Usually these will include gag and pol proteins derived from the first retrovirus.

Preferably, the first retrovirus is a lentivirus which provides the ability to infect and transduce non-dividing cells. During the infection process, lentiviruses form a pre-integration complex in the target cell cytoplasm containing integrase, core proteins and the proviral DNA. The complex is able to pass across the nuclear membrane of the target cell, by means of signal sequences in the proteins. Other retroviruses either lack the proteins, or have the proteins but without the appropriate signal sequences. It is therefore expected to be possible in principle to introduce into retroviruses other than lentiviruses the ability to infect non-dividing cells.

Examples of lentiviruses are HIV, SIV, FIV, BLV, EIAV, CEV and visna virus. Of these, HIV and SIV are presently best understood. However, preferred for use in gene therapy would be a non-immunodeficiency lentivirus because the immunodeficiency viruses inevitably bring with them safety considerations and prejudices.

The non-lentiviral expression control element will usually be a promoter which term includes known promoters, in part or in their entirety, which may be constitutively acting or it may be a regulated promoter inducible only under certain conditions e.g. in the presence of a regulatory protein. This enables expression of the selected gene or genes to be restricted e.g. to particular cell types or to cells in which a particular exogenous signal is present. For example, heavy metal induction of a

gene could be achieved by using components of the metallothionein promoter. Expression control by a steroid hormone may be another useful approach. Brain-specific, stem cell specific or tumour-specific gene expression signals might alternatively be used.

The non-lentiviral promoter replaces the lentiviral protein dependent promoter function of the lentiviral 5' LTR. For HIV, this means that the 5' LTR is no longer responsive to the HIV Tat protein. Tat acts on the TAR region of R; in an HIV-based vector according to the invention functional TAR sequences are therefore absent in order to avoid reductions of translation by the TAR structure. Enhancer sequences contained in the HIV U3 regions are also preferably excluded. A straightforward way to achieve the desired vector LTRs is therefore to replace the lentiviral R regions and as far as possible the U3 regions, but leaving essential lentiviral sequences present such as a short sequence of the U3 region necessary for integration.

As will be evident, in order to function as a vector the retroviral vector particle according to the invention will need to have a reverse transcription system (compatible reverse transcriptase and primer binding sites) and an integration system (compatible integrase and integration sites) allowing conversion to the provirus and integration of the double-stranded DNA into the host cell genome. Additionally, the vector genome will need to contain a packaging signal. These systems and signals are described in more detail below in the Examples and will generally be provided by the first retrovirus, on which the vector is based. It will be evident also that although the vector according to the invention is based on a particular first retrovirus, this may be a genetically or otherwise (e.g. by specific choice of packaging cell system) altered version of the retrovirus. For example, portions of the first retroviral genome not required for its ability to be packaged, undergo reverse transcription and integrate, can be excluded. Also, the vector system can be altered e.g. by using different env genes to alter the vector host range and cell types infected or

transduced.

It may be advantageous to include further elements of the retrovirus on which the vector is based. For HIV this might include functional rev and RRE sequences, enabling efficient export of RRE-containing RNA transcripts of the vector genome from the nucleus to the cytoplasm of the target cell.

The ~~selected gene or~~ gene(s) of interest ~~under the control of the promoter in the proviral 5' LTR is or~~ are chosen according to the effect sought to be achieved. For gene therapy purposes there will be at least one therapeutic gene encoding a gene product which is active against the condition it is desired to treat or prevent. Alternatively or additionally, there may be a ~~selected~~ gene which acts as a marker by encoding a detectable product. Therapeutic genes may encode for example an anti-sense RNA, a ribozyme, a transdominant negative mutant of a target protein, a toxin, a conditional toxin, an antigen that induces antibodies or helper T-cells or cytotoxic T-cells, a single chain antibody or a tumour suppresser protein.

The selected gene or genes between the LTRs in the DNA provirus is or are under the transcriptional control of the promoter in the 5' LTR but not otherwise operably linked to any other promoter from the vector. Thus, expression of the selected gene or genes is in a single transcription unit. However, as will be discussed below there may be additional transcription units within the vector genome. These should not interfere with the transcription unit containing the selected gene or genes.

Where two or more genes are present and under transcriptional control of the 5' LTR promoter, there may be an internal ribosome entry site (IRES) e.g. from picornaviral RNA, to allow both genes to be separately translated from a single transcript. Retroviruses incorporating IRES sequences have been constructed by others.

A further gene or genes may also be present under the control of a separate promoter. Such a gene may encode for example a selectable marker, or a further therapeutic agent which may be among the

therapeutic agents listed above. Expression of this gene may be constitutive; in the case of a selectable marker this may be useful for selecting successfully transfected packaging cells or packaging cells which are producing particularly high titers of the retroviral vector particles. Alternatively or additionally, the selectable marker may be useful for selecting cells which have been successfully infected with the ~~retro~~lenti viral vector and have the provirus integrated into their own genome.

One way of performing gene therapy is to extract cells from a patient, infect the extracted cells with a ~~retro~~lenti viral vector and reintroduce the cells back into the patient. A selectable marker may be used to provide a means for enriching for infected or transduced cells or positively selecting for only those cells which have been infected or transduced, before reintroducing the cells into the patient. This procedure may increase the chances of success of the therapy. Selectable markers may be for instance drug resistance genes, metabolic enzyme genes, or any other selectable markers known in the art. ← insert (H) from p. 7 of doc WO 9813074

However, it will be evident that for many gene therapy applications of ~~retro~~lenti viral vectors, selection for expression of a marker gene may not be possible or necessary. Indeed expression of a selection marker, while convenient for *in vitro* studies, could be deleterious *in vivo* because of the inappropriate induction of cytotoxic T lymphocytes (CTLs) directed against the foreign marker protein. Also, it is possible that for *in vivo* applications, vectors without any internal promoters will be preferable. The presence of internal promoters can affect for example the transduction titres obtainable from a packaging cell line and the stability of the integrated vector. Thus, single transcription unit vectors, which may be bi-cistronic or poly-cistronic, coding for one or two or more therapeutic genes, may be the preferred vector designed for use *in vivo*.

It will be evident that the term "gene" is used loosely here, and includes any nucleic acid coding for the desired polypeptide. Usually, the genes delivered by the vector according to the invention will be cDNAs.

It is desirable for the purposes of gene therapy that the retroviral vector genome does not encode any unnecessary polypeptides, that is any polypeptides that are not required for achieving the effect the vector is designed for. In any case, the retroviral vector will be replication defective. Thus, it is necessary to exclude from the vector genome full-length *gag-pol* or *env* coding regions, or preferably both. This has the dual purpose of avoiding unwanted immune responses directed against the foreign viral proteins, and reducing the possibility of a replication competent retrovirus being generated by recombination.

The retroviral vector particle according to the invention will also be capable of infecting and transducing cells which are slowly-dividing, and which non-lentiviruses such as MLV would not be able to efficiently infect and transduce. Slowly-dividing cells divide once in about every three to four days. Mammalian non-dividing and slowly-dividing cells include brain cells, stem cells, terminally differentiated macrophages, lung epithelial cells and various other cell types. Also included are certain tumour cells. Although tumours contain rapidly dividing cells, some tumour cells especially those in the centre of the tumour, divide infrequently.

DNA constructs encoding the vector genome described herein are preferably linked to a high efficiency promoter such as the CMV promoter. Other high efficiency promoters are known. This gives rise to a high level of expression of the vector RNA in the host cell producing the retroviral vector particles.

Suitable host or producer cells for use in the invention are well known in the art. Many ~~retro~~lentiviruses have already been split into replication defective genomes and packaging components. ~~For those~~ In a set which have not the technology is available for doing so. The producer cell encodes the viral components not encoded by the vector genome such as the gag, pol and env proteins. The *gag*, *pol* and *env* genes may be introduced into the producer cell (transiently) or may be and stably integrated into the cell genome to give a packaging cell line. The ~~retro~~lentiviral vector genome is then introduced into the packaging

cell line by transfection or transduction to create a stable cell line that has all of the DNA sequences required to produce a retroviral vector particle. Another approach is to introduce the different DNA sequences that are required to produce a retroviral vector particle e.g. the *env* coding sequence, the *gag-pol* coding sequence and the defective retroviral genome into the cell simultaneously by transient triple transfection (Landau & Littman 1992 J. Virol. 66, 5110; Soneoka *et al* 1995).

The strategy according to the invention has several advantages in addition to those already described. Firstly, by making use of the 5' LTR as the expression signal for a therapeutic transcription unit it is possible to make this vector genome a single transcription unit genome for both production and expression in the transduced cell. This avoids the need for internal promoters between the LTRs. The unpredictable outcome of placing additional promoters within the retroviral LTR transcription unit is well documented (Bowtell *et al*, 1988 J.Virol. 62, 2464; Correll *et al*, 1994 Blood 84, 1812; Emerman and Temin 1984 Cell 39, 459; Ghattas *et al*, 1991 Mol.Cell.Biol. 11, 5848; Hantzopoulos *et al*, 1989 PNAS 86, 3519; Hatzoglou *et al*, 1991 J.Biol.Chem 266, 8416; Hatzoglou *et al*, 1988 J.Biol.Chem 263, 17798; Li *et al*, 1992 Hum.Gen.Ther. 3, 381; McLachlin *et al*, 1993 Virol. 195, 1; Overell *et al*, 1988 Mol.Cell Biol. 8, 1803; Scharfman *et al*, 1991 PNAS 88, 4626; Vile *et al*, 1994 Gene Ther 1, 307; Xu *et al*, 1989 Virol. 171, 331; Yee *et al*, 1987 PNAS 84, 5197). The factors involved appear to include the relative position and orientation of the two promoters, the nature of the promoters and the expressed genes and any selection procedures that may be adopted. The presence of internal promoters can affect both the transduction titers attainable from a packaging cell line and the stability of the integrated vector. Loss of gene expression following transduction can be caused both by provirus deletions and reversible epigenetic mechanisms of promoter shutdown. In addition, data from tissue culture studies can often have no bearing on the performance of the vectors *in vivo*. These considerations suggest that simple retroviral vectors containing a single LTR

promoter are likely to be promising vectors for gene therapy (Correll *et al* 1994 Blood 84, 1812). In addition, with the development of bi-cistronic vectors using only one promoter (Adam *et al*, 1991 J.Virol 65,4985) it will also be possible to produce single transcription unit vectors coding for two or more therapeutic genes, with correspondingly greater efficacy.

The second advantage of removing the HIV expression signals within the U3 and R regions is that these signals are subject to a number of external influences on their activity. It is known that the HIV promoter can be activated by a variety of agents such as UV, stress, other viruses etc. (Peterlin 1992 in Human Retroviruses ed. Cullen. IRL Press) which makes the transcriptional status of the vector genome difficult to control. Removal of these sequences will ensure greater control over the therapeutic gene.

In the attached figures:

Figure 1 shows a general scheme for vectors according to the invention;

Figure 2 shows a generalised HIV-based vector genome according to the invention;

Figure 3 shows the HIV-based vector genome described in Example 1;

Figure 4 shows in more detail the structure of the 3' LTR for the vector in Figure 3.

Figure 5 is a schematic diagram of packaging components;

Figure 6 further shows the principle of vectors according to the invention.

The invention is outlined in Figure 1. The vector system is designated Lentiviral LTR-Deleted (LLD) vector. It comprises a DNA molecule in which a CMV or other high efficiency promoter is used to drive the expression of the vector RNA in a producer cell. This strategy is analogous to the HIT vector system (Soneoka *et al*, 1995 Nucl.Acids Res. 23, 628). The producer cell will have been engineered to produce compatible lentiviral structural proteins and enzymes. It will be, therefore,

what is known as a vector packaging cell. The producer DNA can be used as an autonomous plasmid that either does or does not replicate or it can be integrated into the producer cell genome. All of these strategies are known in the field (Soneoka *et al*, 1995 Nucl.Acids Res. 23, 628; Miller and Rossman 1989 BioTech. 7, 980; Miller 1990 Hum.Gene Ther. 1, 5). The producer DNA for the vector genome may contain at least the following contiguous components: A high efficiency promoter, a non-lentiviral R region that either comes from another retrovirus or is completely synthetic, all or part of the lentiviral U5 region that contains sequences required for integration by the lentiviral integrase and sequences necessary for efficient reverse transcription, packaging signals that are recognized by the packaging components of the producer cell, an internal region that might contain genes including therapeutic or reporter genes or selectable markers and associated expression signals (in addition the internal region might contain components of systems for ensuring efficient RNA splicing and transport), a second strand primer site from the lentivirus, a short sequence of 30-100 nucleotides from the lentivirus U3 region that is required for efficient integration by the lentivirus integrase, a heterologous promoter that might confer tissue specificity of gene expression or regulation by an exogenous signal so that a therapeutic gene can be expressed appropriately, an R region that is identical to the first R region together with transcription termination and polyadenylation signals required to produce a vector RNA with terminal R regions. This producer DNA produces an RNA molecule that is packaged by the lentiviral packaging system. The resulting vector particles will deliver that RNA to a susceptible cell, the RNA will be converted to DNA by the lentiviral reverse transcriptase and it will be integrated into the cells genome by the lentiviral integrase. The resulting provirus will have the CMV promoter component of the producer DNA replaced by the short lentiviral sequence from the end of the lentiviral U3 region and the heterologous promoter that may confer tissue specific or regulated gene expression. Because the lentiviral R region has been entirely

replaced there are no inhibitory TAR sequences in the integrated vector genome.

EXAMPLES

EXAMPLE 1

An HIV-based LLD vector with the MLV U3 promoter and MLV R regions.

The structure of a general HIV LLD vector system is shown in Figure 2. This example is shown in Figures 3 and 4. It is constructed as follows. The minimal requirements for HIV reverse transcription are the primer binding site (PBS) to initiate the negative strand DNA synthesis, the polypurine tract (PPT) to initiate the positive DNA synthesis, and identical 5' and 3' R sequences to allow the first template switch. The incorporation of the PBS and PPT from HIV-1 into the vector and the R sequences from MLV into both LTRs is therefore required. As secondary structure within the 5' U5 region might be important for reverse transcription, the U5 region in the 5' LTR is from HIV-1. For the U5 region at the 3' LTR, the U5 from HIV-1 was used to make sure correct termination of transcription occurred at the R-U5 border. However, any termination signals could be used. For efficient integration, 30 nucleotides at the 5' end of the HIV-1 U3 at the 3' LTR were incorporated.

In order for the MLV U3 element to appear in the 5' LTR after reverse transcription, it must be in the 3' LTR of the viral RNA. The whole MLV U3 except 30 bps of the 5' end replaced the HIV-1 U3. The 3' LTR of the vector was designed to contain several convenient restriction sites, so that the MLV U3 can be easily replaced by other heterologous promoters (Figure. 4). Any heterologous promoters will be amplified by PCR with primers containing StuI and NarI sites at each end and will be used to replace the MLV U3. Not only StuI but also NheI and AflII may be used at the 5' end of the promoter cassettes. NarI(GGCGCC) is located on the

junction between the promoter and R, so that the transcription start site from the heterologous promoter can be preserved. The MLV U3 sequences between XbaI and NarI contains the basic promoter elements including TATA box, GC box, and CAAT box. Therefore the MLV enhancer can be replaced by any other enhancers as a StuI (or NheI or AflII) - XbaI cassettes.

For efficient packaging 353 nucleotides of gag is known to be sufficient (Srinivasakumar *et al*, 1996 CSH Retrovirus Meeting abstract). The 353 nucleotides of gag sequences corresponds to the sequences from 790 to 1144 within this three ATG's (790, 834, 894) were removed by mutation. In addition a polycloning site is located downstream of gag.

In order to achieve efficient export of RNA species encoded by HIV genome, rev and RRE are required. They are included in the LLD vector and correspond to sequences 5861 to 6403 and 7621 to 9085 from HIV-1 (HXB2). Tat coding sequence is not present in the vector.

Details of construction of the producer DNA:

A. 5' Structure (All HIV-1 coordinates are from HXB from the Loa Alamos Sequence Database and MoMLV sequences are from Shinnick et al 1981 Nature 293, 543)

The 5' half of the vector contains the hybrid 5' LTR (CMV promoter-MLV R -HIV-1 U5), HIV-1 PBS, and HIV-1 packaging signal. This will be constructed by recombination PCR. One of the templates for the PCR, pHIVdge2, is an HIV-1 proviral DNA which has a mutation created by filling-in and religation at the ClaI site (831) and a deletion between NdeI(6403) and BglII(7621). The junction between MLV R and HIV-1 U5 is created by two primary PCR reactions (using the primer NIT1 and NIT2; NIT3 and NIT4) and a secondary PCR reaction (using the primers NIT1 and NIT4). The PCR product is inserted into pBluesriptKS+ (STRATAGEN) at KpnI and XhoI site (Construct A1). In order to mutate three ATGs in the gag region, the primers contain mutated codons.

NIT1: 5'-ccgggtacccgtattcccaataaagcctcttgctgtttgca-3' (SEQ ID NO: 1)

NIT2: 5'-ctacgatctaattctcccccgcttaatactgacgctctcgcacctatctc-3' (SEQ ID NO 2)

NIT3: 5'-
gcgggggagaattagatcgtagggaaaaaattcggttaaggccaggggggaaagaaaaaatataaattaaaacatatagtttggg-3' (SEQ ID NO: 3)

NIT4: 5'-gaattctcgaggcgtgctgtgctttttttctatc-3' (SEQ ID NO: 4)

The CMV promoter - MLV R fragment is amplified by PCR from pRV109 (Soneoka *et al*, 1995) to contain KpnI sites at both ends using the PCR primers NIT5 and NIT6 and inserted into construct A1 to produce construct A2.

NIT5: 5'-gtaggtacccgttacataacttacggtaaatg-3' (SEQ ID NO: 5)

NIT6: 5'-agaggctttattgggaatacg-3' (SEQ ID NO: 6)

B. 3' Structure

The 3' half of the vector genome includes the HIV-1 rev coding region and RRE, PPT, ,36 bp of 5' end of HIV-1 U3, and the whole MLV LTR except 30 bp of 5'end. The sequences (5861-6000) are PCR amplified from pHIVdge2 (using NIT7 and NIT8) and are subcloned into pSP64 (PROMEGA) at BamHI and SacI site (Construct B1).

NIT7: 5'-cacggatccactagttggaagcatccaggaagtcagc-3' (SEQ ID NO: 7)

NIT8: 5'-ctctgactgttctgatgagc-3' (SEQ ID NO: 8)

The SacI-SacI fragment (6000 - 6403 and 7621 - 9572) from pHIVdge2 is inserted into the above construct to produce construct B2. Finally the HIV-1-MLV hybrid LTR will be created by two primary PCRs (using NIT9 and NIT10 with pHIVdge2 as the template; NIT11 and NIT12 with pLXSN (Accession number M28248; Miller *et al*, 1989) as the

template) and one secondary PCR reaction (using NIT9 and NIT12). The PCR product will be inserted at the XhoI and EcoRI sites in Construct B2 to produce Construct B3.

NIT9: 5'-gagcagcatctcgagacctgg-3' (SEQ ID NO: 9)

NIT10: 5'-tggcgttacttaagctagcaggcctgtcttctttgggagtgttttagc-3' (SEQ ID NO: 10)

NIT11: 5'-cccaaagaagacaggcctgctagcttaagtaacgccatttttcc-3' (SEQ ID NO:11)

NIT12: 5'-cctgaattccgcggaatgaaagacccccgctgacg-3' (SEQ ID NO: 12)

C. Complete Vector

The two halves of the vector are combined by inserting the SpeI-SacII fragment from construct B3 into construct A2. The resulting construct, C1, possesses a poly-cloning site; XhoI-SalI-ClaI-HindIII-EcoRV-EcoRI-PstI-SmaI-BamHI-SpeI (underlined sites are unique in the vector) . This plasmid is designated pLLD1 and the retroviral vector that it produces is LLD1.

The β-galactosidase gene was then taken from pSP72-lacZ (XhoI-BamHI) and inserted into the construct C1 at SalI and BamHI to produce LLD1-lacZ. This was used to transfect 293T cells together with plasmids providing the HIV gag and pol components (pRV664, Figure 5) and either a plasmid expressing gp160 from HIV (pRV438 or pSynp160mn, Figure 5) or a plasmid expressing the VSVG protein (pRV67, Figure 5). Any plasmids encoding the same proteins would work equally well. The resulting virus that is produced transduced the lacZ gene to CD4+ Hela cells in the case of virus containing gp160 and to CD4- Hela cells in the case of the VSVG bearing virus. In addition the VSVG bearing virus delivers lacZ to post-mitotic neurones. In each case the expression of the lacZ gene is high, as determined by Xgal staining, and independent of Tat.

EXAMPLE 2

Other LLD vectors.

Systems similar to that described in Example 1 can be produced from other lentiviruses. These systems avoid using HIV, with its associated perceived risks as a gene delivery system. For example constructions could be designed using sequence information from FIV (Talbott *et al*, 1989 PNAS 86, 5743), EIAV (Payne *et al*, 1994 J.Gen.Virol. 75, 425), Visna virus (Sonigo et al 1985 Cell 42, 369; Querat *et al*, 1990 Virology 175, 434), BIV Garvey *et al*, 1990 Virology 175, 391) and SIV (Los Alamos sequence database).

Figure Legends

Figure 2. Example: HIV-based LLD vector.

Superscript H = HIV-derived sequence (could be from any lentivirus).

Superscript M = MLV-derived sequence.

ψ = Packaging site (including gag region).

PBS = Second strand priming site.

INTERNAL = Region containing genes, selectable markers, other promoters or RNA handling systems such as HIV RRE and Rev coding sequences.

Figure 3. NIT vector genome (Inserts 3789 bp + backbone 2929bp = 6718 bp):

HCMV promoter (-521 to –1) from pRV109.

HIV sequences (552 to 1144; 5861 to 6403; 7621 to 9085) from HXB2.

Genotype; gag-; pol-; env-; **rev+; RRE**; vif-; vpu-; vpr-; tat-; nef-.

Mutations:

- three point mutations to remove ATG (790, 834, 894) (@)
- a frameshift mutation by two base insertion (831) (*)
- a deletion between NdeI(6403) and BglII (7621) (Δ)

Polycloning site (X); XhoI-SalI-ClaI-EcoRV-EcoRI-PstI-SmaI-BamHI-SpeI; Underlined sites are unique.

Maximal insertion site into the polycloning site: 5997bp.

Backbone; pBluescriptKS+.

Figure 5. Schematic diagram of packaging components.

pRV664 encodes HIV-1 HXB2 gagpol (637-5748) and contains RRE (7720-8054) and its backbone is pCI-neo (PROMEGA).

pRV438 possesses both rev and env from HXB2 (5955-8902) in pSA91 which is a mammalian expression plasmid with CMC promoter. pSYngp 160mn (from B. Seed) is an expression plasmid for HIV-1 MN envelope which was modified to have the optimized codon usage in mammalian cells. pRV67 is a VSV G expression plasmid in pSA91.

CLAIMS

1. A retroviral vector particle based on a first retrovirus, said retroviral vector particle capable of infecting and transducing non-dividing mammalian target cells, said retroviral vector particle comprising a packagable RNA genome capable of being inserted into a target cell genome when in the form of a DNA provirus, said RNA genome comprising sequences which provide in the DNA provirus:

a) a non-lentiviral expression control element located in the 5' long terminal repeat (LTR) of the provirus in place of the promoter function of the first retrovirus; and

b) a selected gene or genes under transcriptional control of the non-lentiviral expression control element in a), the selected gene or genes located between the LTRs.

2. The retroviral vector particle according to claim 1, wherein the first retrovirus is a lentivirus, in which the lentiviral sequence or sequences which normally provide a 5' lentiviral-protein dependent promoter function in the DNA provirus is/are absent.

3. The retroviral vector particle according to claim 1 or claim 2, wherein the lentivirus on which the vector is based is HIV and functional TAR sequences are absent.

4. The retroviral vector particle according to claim 3, wherein the vector genome further comprises functional rev and RRE sequences, enabling export of RRE-containing RNA transcripts of the genome from the nucleus to the cytoplasm of the target cell.

5. The retroviral vector particle according to any one of claims 2 to 4, wherein the lentiviral R regions are replaced by non-lentiviral R regions.

6. The retroviral vector particle according to any one of claims 1 to 5, wherein the non-lentiviral expression control element is a regulated promoter which is inducible by a non-lentiviral regulatory factor.

7. The retroviral vector particle according to claim 6, wherein the regulated promoter is inducible by a non-viral regulatory factor.

8. The retroviral vector particle according to claim 1, wherein the expression control element comprises the MLV LTR promoter.

9. The retroviral vector particle according to any one of claims 1 to 8, wherein the non-lentiviral expression control element comprises non-lentiviral, retroviral U3 and R regions, or functional portions thereof.

10. The retroviral vector particle according to any one of claims 2 to 9, wherein the RNA genome comprises a first non-lentiviral R region, a sufficient portion of the lentiviral U5 region for integration and reverse transcription, a primer binding site for first strand reverse transcription, a packaging signal, an internal region containing at least one selected gene, a primer binding site for second strand reverse transcription, a short sequence of the lentivirus U3 region sufficient for integration, a non-lentiviral promoter, and a second R region substantially identical to the first R region.

11. A DNA construct encoding the packagable RNA genome for the retroviral vector particle according to any one of claims 1 to 10, operably linked to a promoter.

12. The DNA construct according to claim 11, wherein the promoter is a high efficiency promoter.

13. The DNA construct according to claim 11 or claim 12, wherein the selected gene is absent and the construct has an insertion site at which the selected gene or genes may be inserted.

14. A retroviral vector particle production system comprising a host cell transfected or transduced with a DNA construct according to any one of claims 11 to 13, said system capable of producing retroviral vector particles according to any one of claims 1 to 10.

15. A retroviral vector particle production system comprising a set of nucleic acid sequences encoding the components of a retroviral vector particle according to any one of claims 1 to 10.

16. The use of a retroviral vector particle according to any one of claims 1 to 10, for gene therapy for infection and transduction of a target cell.

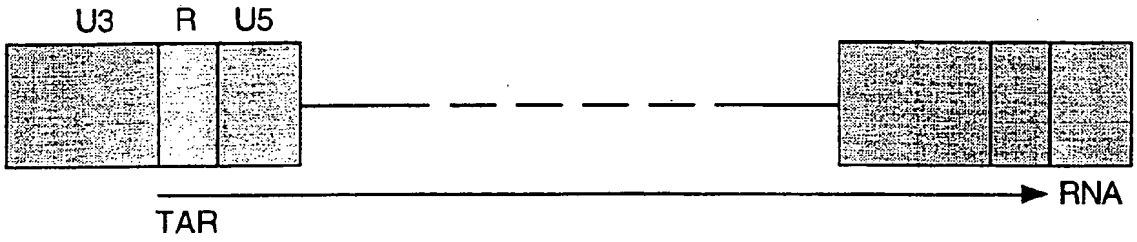
17. The use of a retroviral vector particle according to any one of claims 1 to 10, in the preparation of a medicament for use in gene therapy.

18. A method of performing gene therapy on a target cell, which method comprises infecting and transducing the target cell with a retroviral vector particle according to any one of claim 1 to 10.

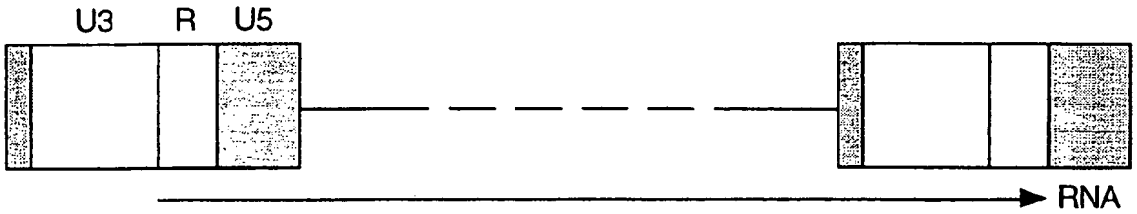
19. Target cells resulting from the use or method according to any one of claims 16 to 18.

Fig.1.

a) Lentivirus genome



b) LLD vector

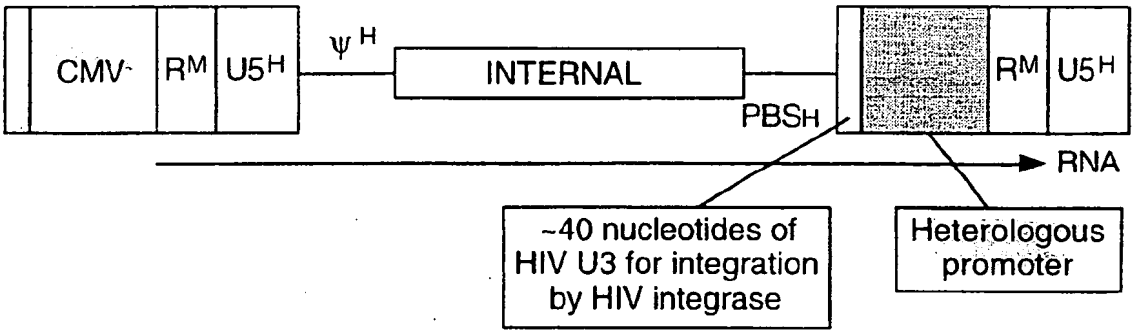


=LENTIVIRAL SEQUENCES

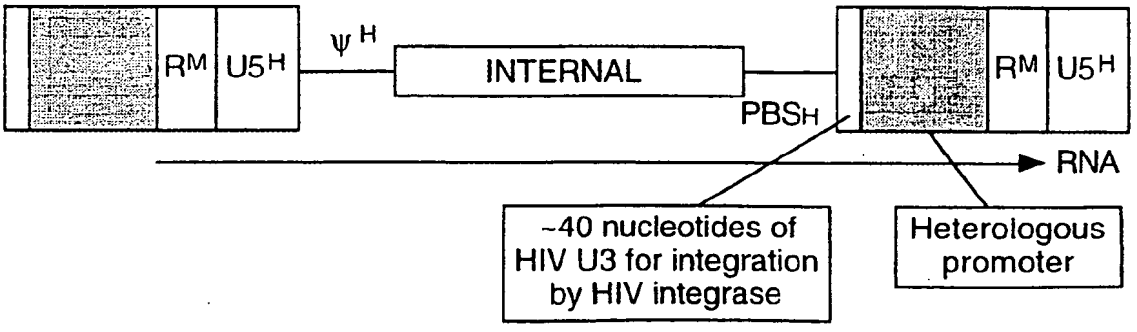
=HETEROLOGOUS SEQUENCES

Fig.2.

a) Producer DNA



b) Integrated LLD vector



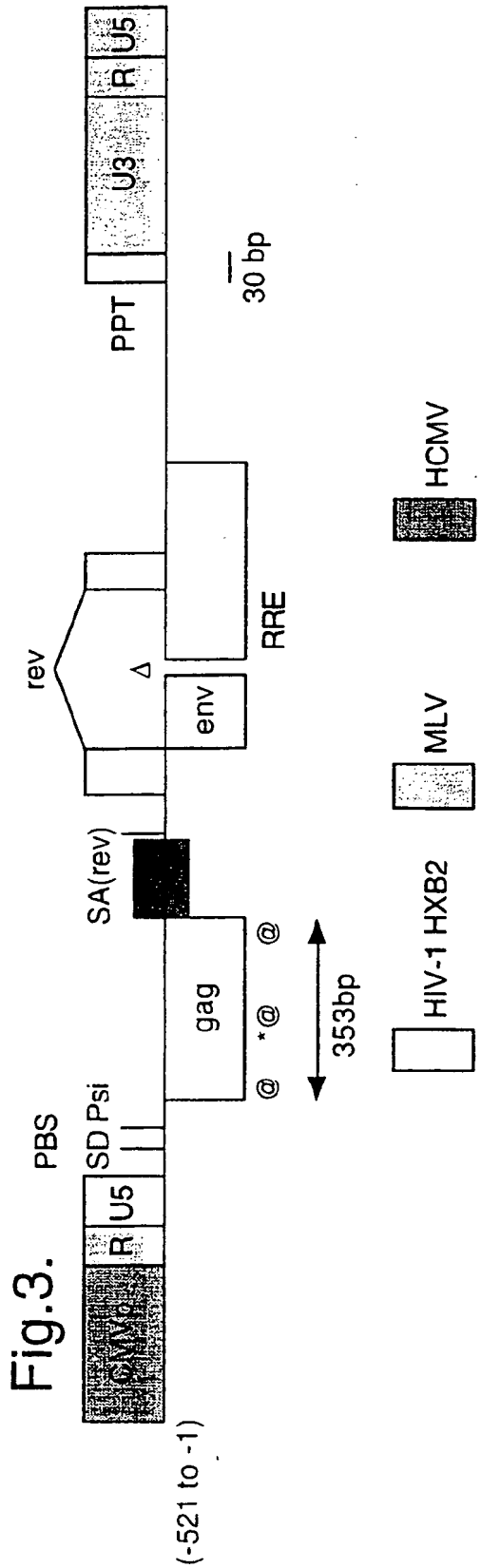


Fig.3.
PBS
SD Psi
SA(rev)
gag
353bp
rev
env
RRE
PPT
30 bp
HCMV
MLV
HIV-1 HXB2
U5
R
U3
(-521 to -1)

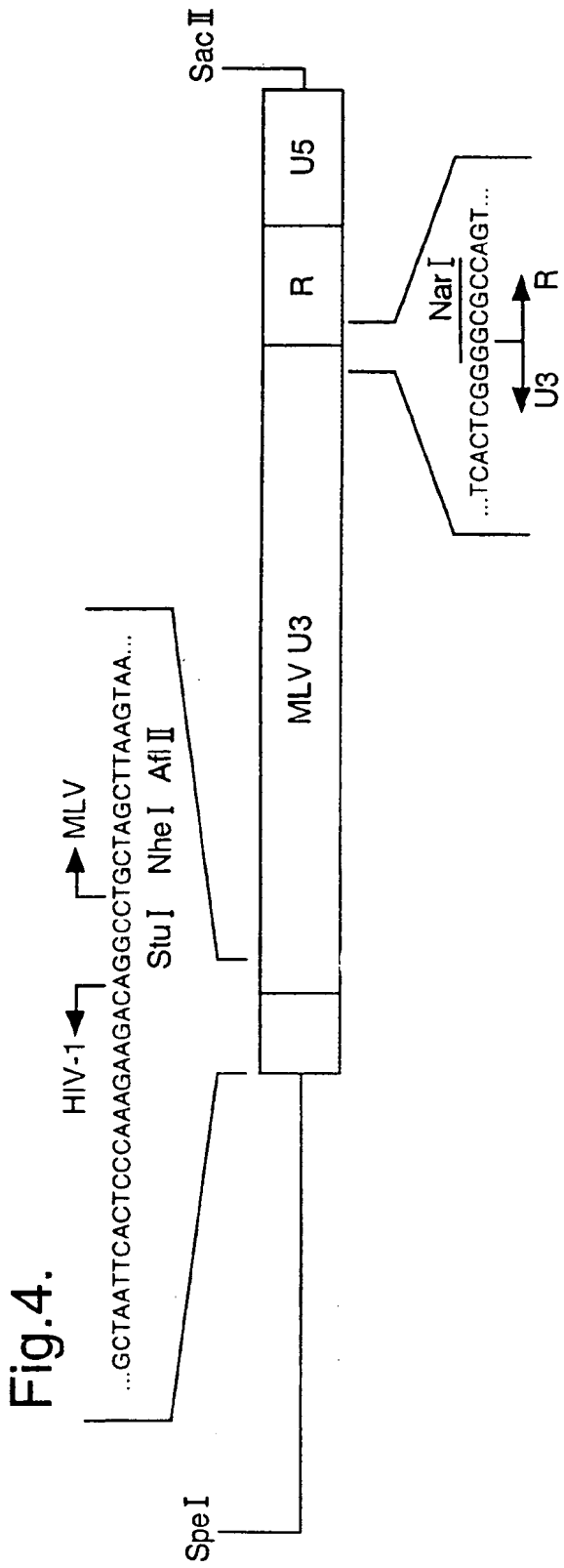


Fig.4.
Sac II
U5
R
MLV U3
Nar I
...TCACTCGGGGCGCCAGT...
U3
R
HIV-1
MLV
...GCTAATTCACTCCCAAAGAAGACAGGCCTGCTAGCTTAAGTAA...
Stu I Nhe I Afl II
Spe I

Fig.5.

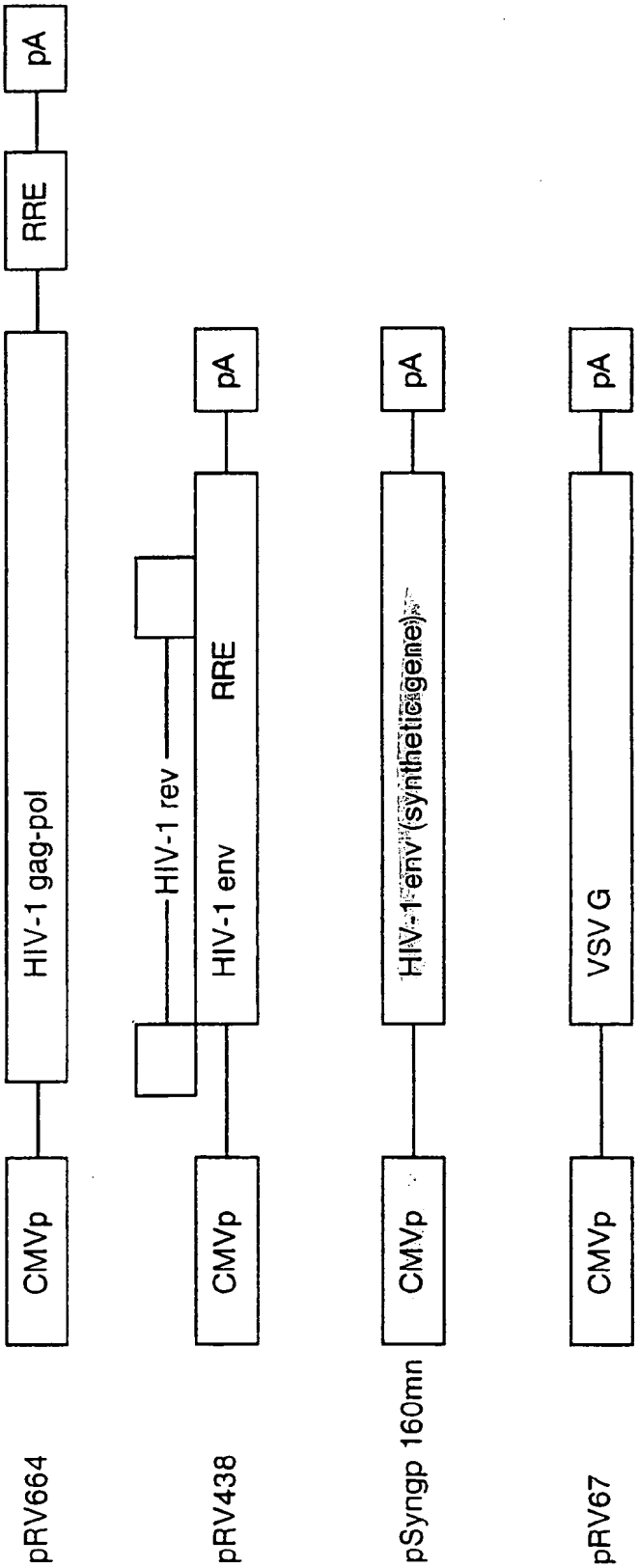
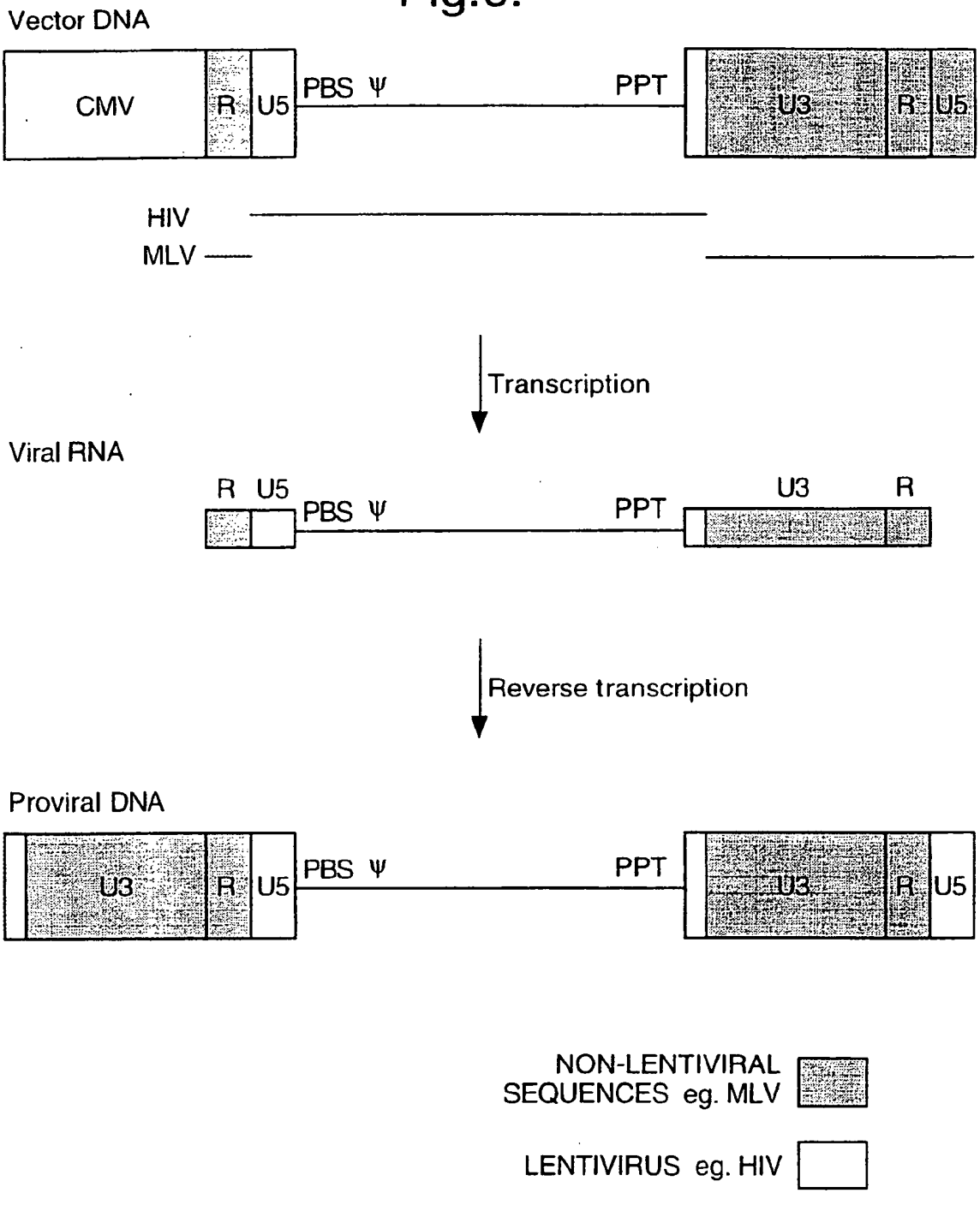

pA
RRE
HIV-1 gag-pol
CMVp
pRV664
pA
HIV-1 rev
HIV-1 env
RRE
CMVp
pRV438
pA
HIV-1 env (synthetic gene)
CMVp
pSyngp 160mn
pA
VSV G
CMVp
pRV67

Fig.6.


Vector DNA
CMV
R
U5
PBS
Ψ
PPT
U3
R
U5
HIV
MLV
Transcription
Viral RNA
R
U5
PBS
Ψ
PPT
U3
R
Reverse transcription
Proviral DNA
U3
R
U5
PBS
Ψ
PPT
U3
R
U5
NON-LENTIVIRAL SEQUENCES eg. MLV
LENTIVIRUS eg. HIV

INTERNATIONAL SEARCH REPORT

International Application No
PC., GB 97/02858

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12N15/86 C12N15/49 A61K35/76 C12N7/00 - C12N5/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12N A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 32300 A (UNIV MEDICINE & DENTISTRY OF N) 30 November 1995 see the whole document ---	1,2,4,6, 11-19
X	WO 96 28563 A (BAVARIAN NORDIC ;GSF FORSCHUNGSZENTRUM UMWELT (DE); GUENZBURG WALT) 19 September 1996 see the whole document ---	1,2,4, 6-9, 11-19
X	WO 96 14332 A (CHANG LUNG JI) 17 May 1996 see the whole document ---	1,2,4,9, 11-19
P,X	WO 96 37623 A (OXFORD BIOMEDICA LTD ;KINGSMAN ALAN JOHN (GB); KINGSMAN SUSAN MARY) 28 November 1996 cited in the application see the whole document ---	1,11-19
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

Date of the actual completion of the international search	Date of mailing of the international search report
26 February 1998	17.03.98
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Smalt, R

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	WO 97 48277 A (SALK INST FOR BIOLOGICAL STUDI ;GAGE FRED H (US); SUHR STEVEN T (U) 24 December 1997 see page 5, line 17 - page 6, line 19 see page 13, line 14 - line 17; claims 9,14 see page 9, line 8 - line 18	1-4,6-8, 11-19
A	WO 92 21750 A (US GOVERNMENT) 10 December 1992 see the whole document	4
A	PAULUS W ET AL: "SELF-CONTAINED, TETRACYCLINE-REGULATED RETROVIRAL VECTOR SYSTEM FOR GENE DELIVERY TO MAMMALIAN CELLS" JOURNAL OF VIROLOGY, vol. 70, no. 1, January 1996, pages 62-67, XP002033324 see the whole document	7
A	WO 95 30755 A (HISAMITSU PHARMACEUTICAL CO ;SHIMADA TAKASHI (JP); AKIYAMA KATSUHI) 16 November 1995 see figure 1 & EP 0 759 471 A	12
A	PAROLIN, C. ET AL.: "Use of cis- and trans-acting viral regulatory sequences to improve expression of human immunodeficiency virus vectors in human lymphocytes" VIROLOGY, vol. 222, 15 August 1996, pages 415-422, XP002056866 see abstract	1-6,8,9, 11-19

2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 97/02858

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

see FURTHER INFORMATION sheet PCT/ISA/210

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 97/02858

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Remark : Although claims 16 and 18 are directed to a method of treatment of the human/animal body , the search has been carried out and based on the alleged effects of the compound/composition.

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

Interr nal Application No
PCT/GB 97/02858

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9532300 A	30-11-95	NONE	
WO 9628563 A	19-09-96	AU 5103996 A	02-10-96
		EP 0817858 A	14-01-98
WO 9614332 A	17-05-96	US 5693508 A	02-12-97
		AU 4321596 A	31-05-96
		EP 0791010 A	27-08-97
WO 9637623 A	28-11-96	NONE	
WO 9748277 A	24-12-97	NONE	
WO 9221750 A	10-12-92	AU 2007392 A	08-01-93
		CA 2109579 A	10-12-92
		EP 0588914 A	30-03-94
		JP 6510181 T	17-11-94
WO 9530755 A	16-11-95	AU 2419595 A	29-11-95
		EP 0759471 A	26-02-97